NOTES FROM PACIFIC COAST OBSERVATORIES

The Spectrum of Nova Aquilae

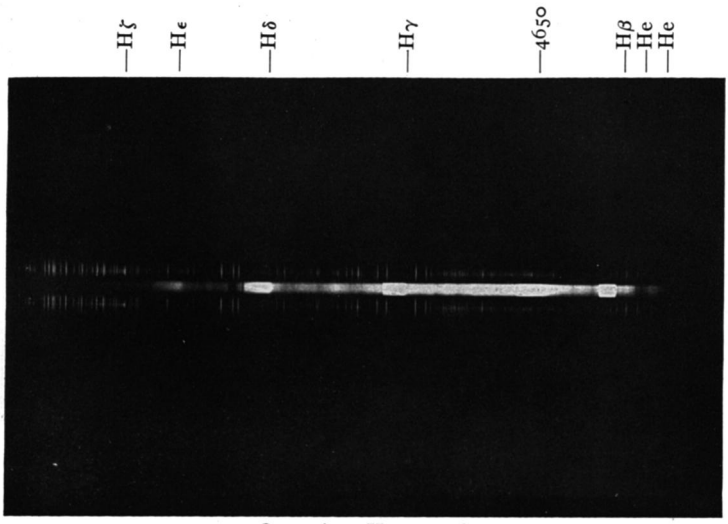
The spectrum of *Nova Aquilae* has shown great complexity and almost continual change. Observations have been obtained with the 36-inch telescope each night from June 10th to July 8th and on many nights since the latter date, its diminishing brightness in July making observations on every night less necessary. Much time and study must be given to the plates fully to describe the spectrum and its changes and to derive any laws or relations contained in them. Only a brief description can be given here.

Five spectrographs have been used: the Mills' three-prism, having wave-length 4500A central, and covering the spectrum from Hγ to Hβ; a three-prism having the yellow D sodium lines central, and covering the region 5300A to Hα; a one-prism having the D lines central, and extending over the region Hγ to Hα; a one-prism with Hγ central and taking in the spectrum from Hζ to Hβ; and the quartz spectrograph, having 3700A central, attached to the Crossley reflector. Observations were begun with the Mills' spectrograph on June 10th. The quartz spectrograph was used on June 12th and 13th. The other instruments have been in use since June 14th, and give a nearly continuous record of the spectrum included between the red hydrogen band Hα and the violet hydrogen band Hζ.

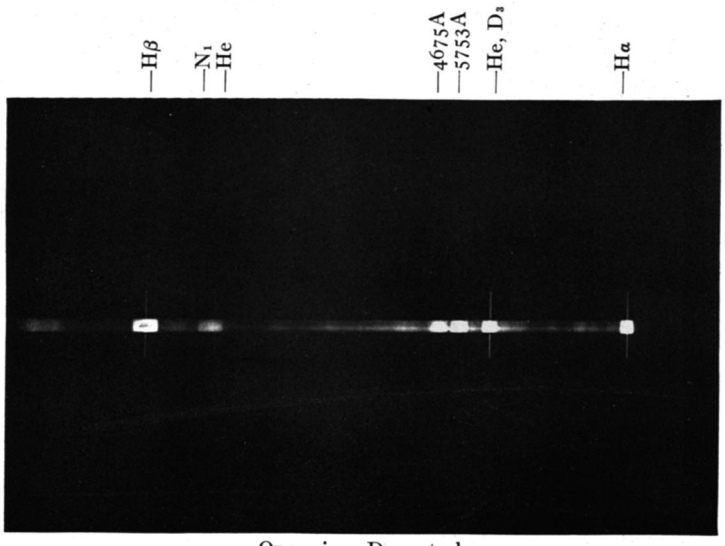
The conspicuous features of the spectrum have been: the strong continuous spectrum and numerous broad absorption lines; the strong, broad, bright hydrogen bands with accompanying sharp absorption lines on their violet sides; the bright bands of helium; and fine absorption lines of calcium and sodium.

The conspicuous changes in the spectrum have been: the gradual fading of the continuous background and the continual strengthening of the bright bands; the increasing and decreasing intensities and changing sharpness of the absorption lines at the violet borders of the bright bands; sudden strengthening and sharpening of other absorption lines, particularly a pair at 4058A and 4064A; the complex changing of absorption bands and lines superposed on every bright band; and, most remarkable of all, the gradual shifting from night to night of the absorption bands toward the violet.

The latter phenomenon is distinctly shown by the three-prism plates of the region between Hγ and Hβ. Measures of two of these



One prism, Hγ central



One prism, D_3 central

FIG. 7. SPECTRUM OF NOVA AQUILAE 1918

bands, at first near 4527A and 4549A, indicate a progressive shift toward the violet averaging three-quarters of an angstrom per day for five or six days and then decreasing with the fading and diffusing of the absorption bands. The dates and displacements with respect to titanium comparison lines are approximately the following:

DATE	BAND NEAR	DIFF.	BAND NEAR	DIFF.
1918	4527A		4549A	
June 10	+0.3 A		0.0 A	
11	−0.8	1.1	−0.3	0.3
12	−1.3	0.5	−1.1	0.8
13	−2.3	1.0	−2.2	1.1
14	−2.9	0.6	−2.3	0.1
15	−3.5	0.6	−3.0	0.7
16	−3.7	0.2	−3.2	0.2
17	−3.8	0.1		
18	−4.0	0.2		
19	−4.0	0.0		

Many other remarkable changes may be noted. From June 10th to 15th the absorption lines accompanying the bright hydrogen bands appeared to be in pairs and each line closely doubled. The more refrangible line of each pair seemed the stronger at first, but diminished and was hardly visible after the 15th. The less refrangible line of the pairs on the other hand became stronger and sharper. The behavior at Hβ differs from that at the other hydrogen bands, a broad absorption band or group of faint absorption lines appearing in place of the strong line. This strong line, which seems to define the more refrangible edge of each bright hydrogen band, and all the edges of the bright hydrogen bands increased in sharpness until June 26th when almost every feature of the spectrum became more or less diffused, the border lines disappearing and the broad absorption bands seen on early plates strongly reappearing. This change was coincident with an increase in brightness of the Nova. This condition continued, with diminishing intensity of the absorption bands, until July 1st, when the sharp and narrow absorption lines on the violet edges of the bright hydrogen bands began to reappear, very finely and closely doubled. They remained with less intensity than before up to July 9th and then seemed to be absent until the 14th.

The pair of strong absorption lines, mentioned above, at 4058A and 4064A (on June 21st) present extraordinary changes. They did not appear until June 15th, when the less refrangible of the pairs of absorption lines accompanying the bright hydrogen bands had nearly vanished. They remained in a broad diffuse condition with a variable amount of shifting toward the violet until June 25th, when they became quite sharp and narrow and displaced toward the violet about ten angstroms from their earliest position. On June 26th, when the whole spectrum became diffuse, these lines completely disappeared. They suddenly reappeared on July 2nd, broad and diffuse and many times stronger than on any previous plate and shifted about the same amount as on June 25th. With varying position and sharpness they remained until July 9th, then vanished as did the other sharp absorption lines and reappeared again on July 14th.

In the yellow and red regions, for which the plates were stained with Wallace's pinacyanol-pinaverdol-homocol solution, conspicuous changes have occurred, but the times do not appear to be the same as the critical dates noted for the changes in the other part of the spectrum. A broad bright band is seen symmetrically placed with respect to the two sodium lines D_1 and D_2 up to June 21st. Plates of June 19th show the band bordered on each side with a pair of narrow absorption lines and crossed by narrow lines corresponding to sodium comparison and showing a slight displacement toward the violet. On June 22nd a change took place, such that this bright band became symmetrically placed with respect to the helium D_3 comparison line. The narrow absorption lines were then and thereafter faint. The bright band at 5753A, which usually appears along with nebular bands, began to develop about June 18th and has become a persistently strong band with very sharp edges. A bright band close by and to the violet of the latter, and one toward the red from the D_3 band, have developed at times, but with varying intensities and definition, usually appearing diffuse. $H\alpha$ has continually been extremely intense, with edges well defined. This has been noticed visually in the spectroscope, where it has appeared like a brilliant red beacon light.

The bright bands have all shown a complicated structure. At times double absorption bands have seemed to be superposed on the bright bands. Sometimes the bright portion between the absorption bands has been more intense than the outer parts and

across some of these bright middle portions has appeared a fine narrow absorption line. The absorption across some of the bands has sometimes appeared to be composed of numerous fine lines. The bright bands and their accompanying absorption lines on their violet borders have not exhibited the extraordinary shifts seen in the other absorption lines. On the plates of June 22nd and July 1st the widths of the bright hydrogen bands $H\zeta$, $H\epsilon$, $H\delta$, $H\gamma$, range from 42A to 46A. $H\beta$ is 55A wide and $H\alpha$, 80A. He 4922 and 5015 are 54A and D_3 is 62A wide. The band at 5753A is 64A. A gradually developed band about 180A wide lying between 4600A and 4800A probably includes bands 4640-50, 4686, 4713A, the first two of which may be expected to develop from it. On June 23rd the helium band 5015A began to be influenced by the nebular band N_1 (5007A), and likewise soon after that the helium 4922A gave evidence of being affected by the presence of the nebular band N_2 (4959A). By July 10th N_1 and N_2 are distinctly present, the helium bands having diminished in intensity. Along with N_1, N_2, and band 5753A the nebular band at 4363A has appeared, overlapping $H\gamma$. It can be traced back at least to June 22nd.

A plate of the blue $H\gamma$ region with iron spark comparison observed on June 21st and a stained plate of the yellow D_3 region with hydrogen and helium comparison observed on July 1st are here reproduced. They have been measured and the approximate wave-lengths and descriptions of the principal lines, bands, and other features are as follows:

Wave-length	Band	Description
3867A		Absorption line.
	$H\zeta$	Bright band.
3910		Absorption line.
3933	K of Ca	Fine absorption line.
3946		Narrow absorption line.
3947		Narrow absorption line.
3968	H of Ca	Fine absorption line.
	$H\epsilon$	Bright band.
3990		
4058		Strong absorption line.
4064		Strong absorption line.
4078		Narrow absorption line.

Wave-length	Band	Description
4079 – 4123	Hδ	Bright band.
4316		Narrow absorption line.
4317 – 4363	Hγ	Bright band.
4606		Absorption line.
4609 – 4792		Bright band.
4818		Narrow absorption line.
4831		Narrow absorption line.
4834 – 4889	Hβ	Bright band.
4892		Narrow absorption line.
4896 – 4950	He	Bright band.
4990 – 5044	He	Bright band.
4978 – 5032	N_1	Bright band.
5173		Bright band, faint, diffuse.
5318		Bright band, faint, diffuse.
5537		Bright band, faint, diffuse.
5645 – 5706		Bright band.
5721 – 5785		Superposed bright bands and fine absorption line.

Wave-length	Band	Description
5843 5905	He	Bright band.
6299		Bright band, faint, diffuse.
6367		Bright band, faint, diffuse.
6467		Bright band, faint, diffuse.
6520 6600	Hα	Bright band.

The measures of the narrow absorption lines of calcium, H and K, give an approximate displacement toward the violet of four- or five-tenths of an angstrom, or a radial velocity of more or less thirty kilometers per second of approach toward the Sun, if it may be so interpreted.

Many of the above spectral features and changes have been found in previous novae, but space does not permit a comparison here. No discussion will be attempted now, except on the following point: It is probable that the extraordinary shifting toward the violet of the absorption lines is due to an extraordinary increase of refractive index of the absorbing masses or strata. The first case described above occurred after the first maximum of the light of the Nova and the second case was coincident with the second light maximum. This would indicate possibly a different origin of the absorption producing the two groups of bands or lines mentioned.

It will be noticed that this Nova is following the usual spectral transformation, namely, beginning with strong continuous spectrum and absorption bands, then increasing in intensity of the hydrogen bands, then developing nebular bands.

More detailed study and measurement of our long series of spectrograms will yield many other results, the complexity of this spectrum and its changes probably not being exceeded by any previously observed Nova.

Messrs. Moore, Henroteau and Thiele have shared in the observing and Miss L. B. Allen has performed the computations.

July 17, 1918. G. F. PADDOCK.